Seabed Variability and Its Influence on Acoustic Prediction Uncertainty

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LONG TERM GOALS

The long term goal is to assess and characterize uncertainty in the tactical naval environment. The focus is on the contribution of seabed variability to uncertainty in sonar performance predictions. In littoral warfare, the seabed is often a controlling factor in sonar system performance.

OBJECTIVES

The objectives of this effort are to: 1) assess and characterize seafloor variability in shelf environments and 2) determine the impact of the seafloor variability on acoustic prediction uncertainty. The prediction models that we are using include propagation, reverberation and a multi-static system performance model.

APPROACH

Our approach is inherently multi-disciplinary, blending the key disciplines of geology/geophysics (G&G) and acoustics, linked by the field of geoacoustics. For many years, the underwater acoustics community has probed sediment geoacoustics through inverse modeling of acoustic measurements (e.g., propagation, reverberation) or via empirical relations (e.g., Hamilton, 1980) or physics-based models (e.g., Biot, 1962). From the other end, the G&G community has developed its strategies to obtain sediment geoacoustics such as advanced coring, in-situ sampling devices, and modeling (e.g., sediment deposition, transport). These two disciplines, G&G and acoustics, are being merged at the intersection of geoacoustics in order to bring to bear the very best tools of both disciplines and the concomitant synergy upon the problem of Uncertainty. A combination of G&G and acoustics appears to be the best approach to significantly advance the understanding of seafloor variability and its effect on acoustic predictions.

Team members and their associated contributions are provided in Table 1. Figure 1 provides a simple wiring diagram of our team approach. The research to the left largely focuses on goal #1, i.e., determining and characterizing the seafloor variability. In this task we seek to probe and describe finer scales of shallow water variability through advanced G&G and acoustic methods. The research to right corner of Figure 1 largely focuses on goal #2, i.e., acoustic prediction uncertainty resulting from geoacoustic variability and uncertainty. The goal is to determine the model parameters that are the drivers for a specific acoustic prediction. The latest tools developed under the reverberation modeling

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14. ABSTRACT
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15. SUBJECT TERMS

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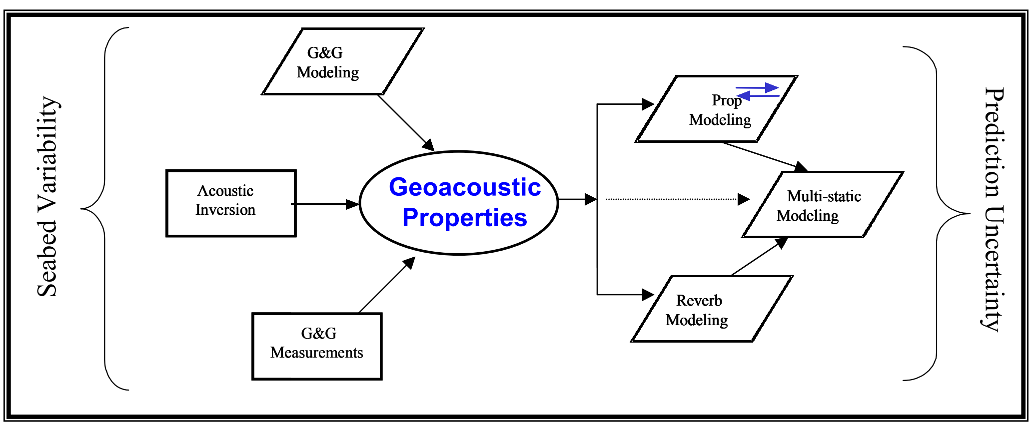
program at SACLANTCEN will be used to conduct the propagation and reverberation portion of these studies.

Table 1. Team members and areas of expertise

Name	**Area of Expertise**	**Affiliation/email**
John Goff	Statistical characterization of sediment properties/morphology	UTIG goff@utig.ig.utexas.edu
Chris Harrison	Multi-static modeling; geoacoustic inversion	SACLANT Centre harrison@saclantc.nato.int
Charles Holland	Seabed reflection and scattering measurements/geoacoustic inversion	ARL/PSU; holland-cw@psu.edu
Kevin LePage	Reverberation modeling	SACLANT Centre lepage@saclantc.nato.int
Larry Mayer	Morphology and in-situ geoacoustic measurements	UNH larry.mayer@unh.edu
Bob Odom	Acoustic propagation modeling (forward/inverse)	APL/UW; odom@apl.washington.edu
Lincoln Pratson	Predictive geoacoustic modeling; lab-generated 3D strata	Duke Un.; lincoln.pratson@duke.edu
James Syvitski	Predictive geophysical modeling	INSTAAR James.Syvitski@colorado.edu



Environmental Variability * Measurement Error * Model/Inversion Error/uncertainty → Acoustic Prediction Uncertainty

Figure 1. Simple diagram showing major task areas and responsible PIs. See text for discussion. The key elements of our total approach include measurements, models, and data, which are represented by the black squares, trapezoids, and ellipses respectively.

WORK COMPLETED

Highlights of work completed this year are as follows, we:

- generated 2D realizations of porosity, permeability, grain size distribution, and bulk density on a canonical margin and on the New Jersey shelf using SedFlux model

- generated 2D realizations of compressional and shear wave speeds and attenuations and density on a on the New Jersey shelf

- developed tools for capturing uncertainty in bathymetry measurements (both multi-beam historical)

- measured in-situ near-surface compressional velocity and attenuation on the New Jersey shelf

- developed statistical model for surficial velocity variability on the New Jersey shelf

- probed relationship between 95 kHz backscatter and geoacoustic properties in an attempt to use backscatter as a proxy for surficial geoacoustic variability on the New Jersey shelf.

- Processed/analyzed broadband seabed reflection data to obtain geoacoustic properties on the New Jersey shelf and on the Tuscany shelf and Malta Plateau

- Developed computationally efficient method to obtain the Frechet derivative, an important metric for assessing impact of geoacoustic uncertainty on acoustic uncertainty.

- Developed tools to capture effect of geoacoustic variability on time domain propagation and reverberation.

- The incorporation of the multi-static modeling in the team is in its very early stages

RESULTS

Using MODAS and other ocean data, and **Hydrotrend** discharge predictions, we characterized the natural variability of the environmental forcing functions controlling the New Jersey shelf. From this natural variability, a series of 2-D **SedFlux** realizations were conducted to capture the variability of the sediment geophysical properties. The geophysical properties were transformed (via Biot theory) into geoacoustic properties (see Fig 2) that can be directly used by the acoustic models.

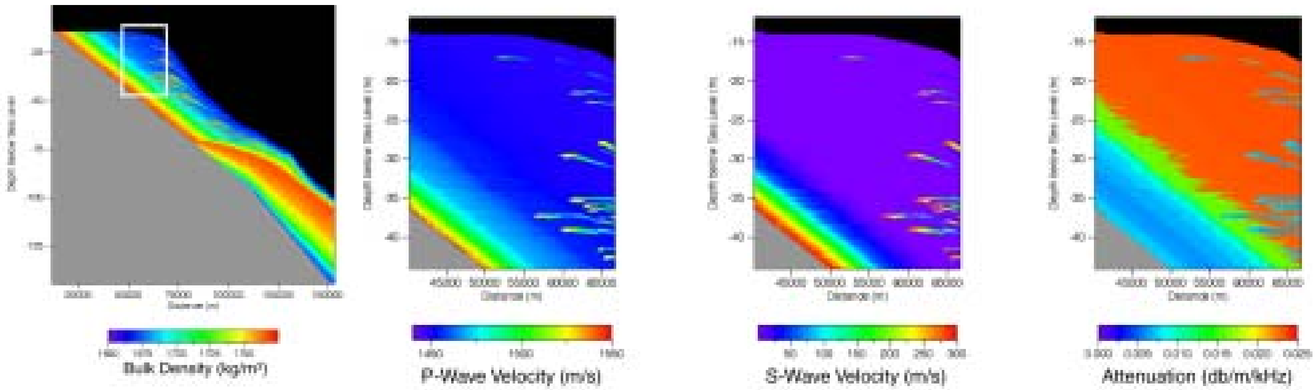


Figure 2. Sedflux predictions of deposition on the New Jersey margin with the associated geoacoustic properties. Fluctuations in the Laurentide ice-sheet melting are responsible for the fine-scale sedimentary structure.

The inherent geoacoustic variability was also probed using acoustic inverse methods. Using space-time, and space-frequency domain methods, sediment geoacoustic properties were inverted from broadband seabed reflection data (see Fig 3a). In-situ surficial compressional wave velocity and attenuation measurements were also conducted. From these data a statistical model was developed to describe the 2D variability of the sediment compressional speed (see Fig 3b). The importance of having three approaches to describe the variability (model based, geoacoustic inversion, and direct sampling) is that they provide a much more complete picture together of the seabed variability than any single approach by itself. In ongoing work, the three descriptions of the geoacoustic variability are being compared and merged.

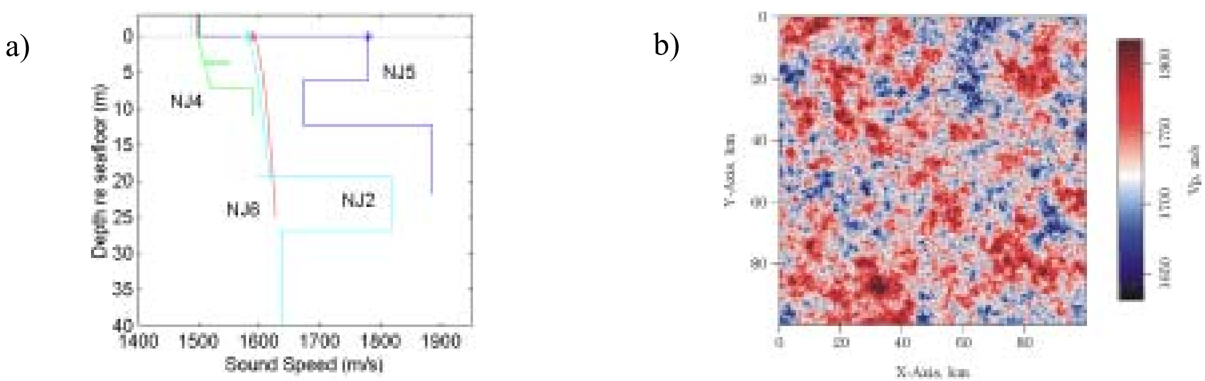


Figure 3. Sediment sound speed variability on the New Jersey shelf; a) estimates at discrete sites based on geoacoustic inversion of reflection data, b) surficial estimates based on in-situ travel-time measurements.

The observed geoacoustic variability is being employed to estimate the impact on acoustic uncertainty. Fig 4 shows predictions from a new, efficient method for computing the Frechet derivative. This is a powerful tool for determining how environmental variability translates into acoustic uncertainty.

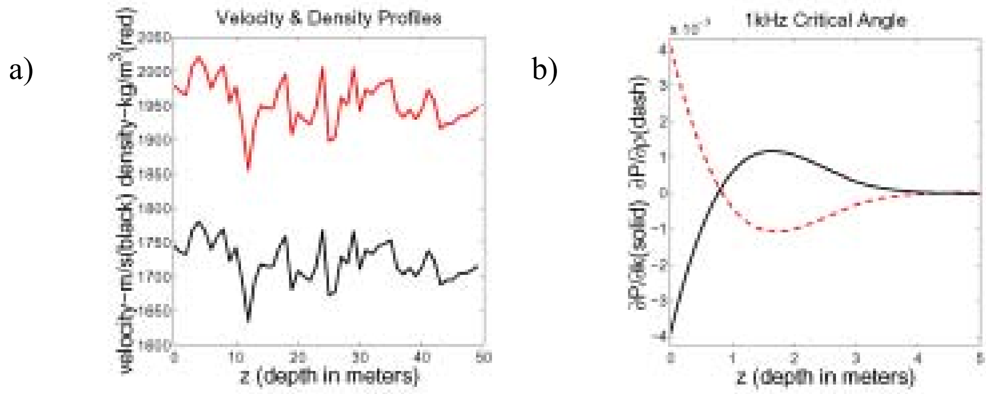


Figure 4. Effects of geoacoustic variability, sound speed (black) density (red), on acoustic propagation on New Jersey shelf: a) estimates of depth depedence, b) Frechet derivative which shows that the variability below about 3m does not impact the acoustic propagation

The effect of seabed variability on pulse propagation was also studied. In Figure 5, each upper plot represents the time series for a single realization of a shallow water waveguide, while the bottom plot shows the expected value of the received field in the presence of environmental variability. When the environmental variability is due to internal waves (Fig 5a), the acoustic variability is manifest only in the leading edge of the wavefront. For the case of sediment variability (Fig 5b) when the sediment interface sound speed is less than that in the water column, the acoustic variability is observed across the entire pulse. We also showed that when the sediment interface sound speed is greater than that in the water column, the acoustic response variability varies only at the coda.

IMPACT/APPLICATIONS

The results of quantifying seabed variability and the tools for transforming that into propagation uncertainty will provide other teams (especially those teams doing an end-to-end approach) the critical data required to carry the effects seafloor variability all the way through to an estimation of uncertainty in Fleet Prediction Products (e.g., tactical decision aids).

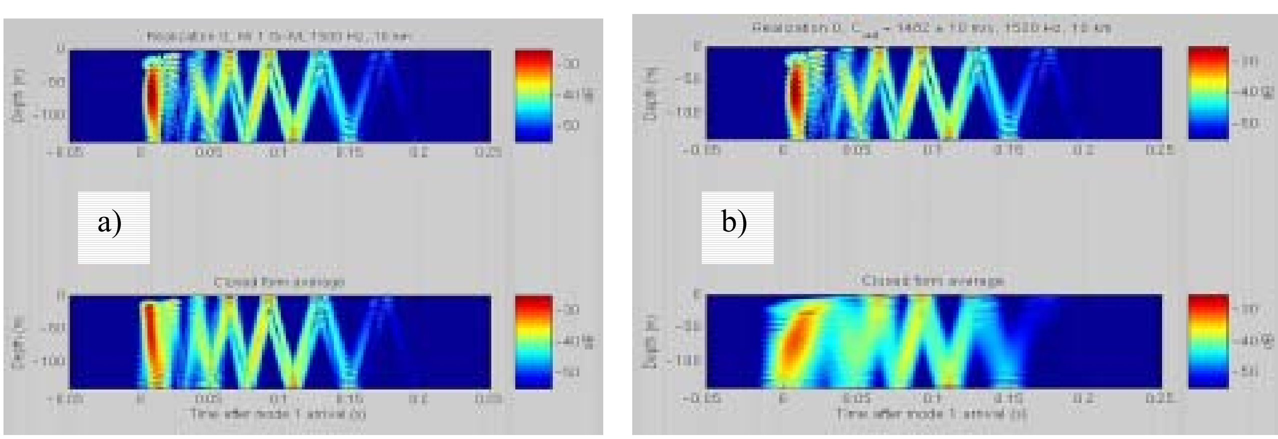


Figure 5. Effects of environmental varaibility on pulse propagation: a) oceanographic variability , b) geoacoustic variability for a slow bottom.

TRANSITIONS

The following products are being transitioned to the other Uncertainty DRI teams.

- tools to quantify bathymetric variability (both historical and multi-beam data)
- statistical seabed velocity models based on statistical analysis of the geoclutter data
- 2D realizations of geophysical properties (density, porosity, permeability) on the NJ shelf
- 2D realizations of geoacoustic properties (p and s speeds/attenuations) on the NJ shelf
- efficient models for computing Frechet derivatives

RELATED PROJECTS

ONR GeoClutter: Providing high resolution G&G, acoustic and geoacoustic data and G&G modeling tools required for estimating seabed spatial variability and uncertainty on the New Jersey shelf.

Boundary Characterization Joint Research Project ONR-NATO SACLANT Centre: Providing high resolution acoustic and geoacoustic data required for estimating seabed spatial variability and uncertainty estimates in the Straits of Sicily and the Tuscany Shelf.

ONR SWAT Program: Collaborating on geoacoustic findings on the New Jersey Shelf.

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